NASA Electronic Parts and Packaging Program (NEPP)

Title: Packaging and Reliability Assessment of MEMS Broad Band Light Sources

(Check one): [X] New Proposal [ ] Continuing NEPP Work

Total $ Requested for FY'01: $ 195K

Technology Type: (check one) [ ] Newly Available (COTS) [X] Emerging/Advanced

Project Area: (check one) [ ] Parts X Packaging [ ] Radiation

Proposing Centers: GRC, JPL

Participating Center(s):

(Estimated Center Participation, %$):

[ ] % GSFC	[50] % GRC	[ ] % LaRC	[50] % JPL
[ ] % MSFC	[ ] % JSC	[ ] Other	

Collaborators: Dr. Margaret L.Tuma and Dr. Robert Okojie (GRC), Eric W. Jones (MDL, JPL), Dr. Rajeshuni Ramesham (JPL), and Dr. Richard Hansler (John Carroll University's Lighting Innovations Institute).

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Investigators: Robert Okojie, Margaret Tuma, Eric Jones, and Rajeshuni Ramesham.

Objectives:
- Validate packaging scheme for the MEMS broad band light sources.**(All)**
- Evaluate reliability of hermetically packaged miniaturized broadband white-light source as a function of thermal compression bonds.**(Eric/Ram)**
- Characterize optical output of packaged device as a function of the sealed gas composition.**(Eric/Glenn)**
- Determine failure modes **of package thermal bonds. (Eric/Ram)**
- Develop guidelines to build robust hermetically packaged and sealed miniaturized light sources.**(All)**

Task Description: To improve the safety and efficiency of future space missions, we plan to test the durability of the packaging of a MEMS light source. This MEMS source was developed by a joint collaboration of JPL, NASA Glenn, and Lighting Innovations Institute and can be used for aeronautical applications as well as for stable optical calibration sources for spectrometers. The use of the low-mass, low-power device will result in considerable savings in launch costs and power consumption of missions. We will
- Evaluate packaging of the MEMS broadband light source in terms of the hermeticity of the thermal compression bonds, filament bonding and ambient conditions of temperature, pressure and humidity.
- Characterize interfaces on bonding metals used to form the hermetic seal as well as the filament bonds.
- Evaluate window materials for maximum optical transmission and durability under various operating conditions and environments.

Task Approach to Meeting NEPP Objectives:
#1. Assess Reliability – Conduct durability and lifetime tests of packaged device to determine failure modes.

#2. Expedite Infusion Path – The characterized device will be assigned specifications for space applications.
#4. Disseminate Information - Published reports of our results will be made available to the NASA community. This new device can then be used in micropropulsion systems and system-on-a-chip technology for the miniaturized spacecraft of the future.

Technical Background: Our advancements using MEMS technology in reducing size, weight, and cost of a light source are critical to meeting the need for advanced instruments and sensors for future ground and space-based NASA applications. Commercial broadband light sources are large in size, require several Watts of electrical power, and give off an enormous amount of heat that must be dissipated. It was determined that in order to utilize the benefits of optical sensors, required a rugged and compact light source. The JPL, NASA Glenn, and Lighting Innovations Institute team have developed a MEMS-based, low-mass, low-power broadband light source, through a joint NASA Glenn – JPL funded program. **Figure 1 shows concept of packaging scheme under investigation.** Advancements in silicon microfabrication technology were used to reduce the size, weight, power consumption and potential cost of the miniature broadband light-source, parameters that are critical to future space applications.

To utilize such a device in space or on earth, we must first complete the packaging of broadband light source and the reliability testing of such packages for flight qualification. **Figure 2 shows one such device being tested in a vacuum chamber.** The basic requirements for several sensor/instrument applications are that the source be stable, long-lived, and have high intensity output. An additional requirement is that the light output be coupled efficiently into an optical fiber. In order to avoid the shortcomings of our predecessors, extensive packaging reliability studies will be conducted. This is to ensure that the devices will perform as per specifications and are worthy of deployment by NASA in future missions. These efforts will consist of determination of package hermeticity due to thermal compression bonds, suitable materials for optical windows for different ambients and operating conditions, and the effects of filament bonding. Such evaluations and characterizations will benefit future generations of packaging designs, leading to more advanced instruments and systems; thus benefiting NASA's goal of faster, better and cheaper missions.

Technical Approach: The following criteria will be used in the approach to evaluating a durable package for the MEMS broadband light source:
1. Technical Soundness: Following an extensive background literature search, we will solicit sample emitters from the NASA microfabrication groups (JPL's Microdevices Laboratory) and commercial fabrication laboratories. The optical output of the miniature device will be monitored while under operation under 2 different conditions, (a) room temperature and (b) temperature cycling from -50^{o}C to 200^{o}C under various packaged gaseous ambients, to assess the reliability of the packaged broad band light source.
2. Originality: The novel device was invented by the Glenn/JPL team which has been successful in its prototype development. Based on our experience with the development of the device, efficient packaging and reliability have been identified as critical needs for flight qualification. Therefore, the above team consisting of the original developers of the device with the addition of packaging and reliability experts has been formed to address the packaging and reliability issues.
3. Relevance to NASA Programs and Projects: This miniature device will reduce the power consumption by 5X. The heat generated by the packaged MEMS source is yet to be determined but will be considerably lower than commercial sources, making it suitable for space applications. There are plans at GRC to utilize optical sensors in the Spaceliner 100 as proposed in the 2001 budget.
4. Qualified resources and experience: NASA Glenn and JPL have resources at their respective facilities enabling them to conduct the proposed tests. These facilities include: ovens capable of heating the packages within the specified temperature ranges, optical test equipment including fibers and detectors for testing the device under different temperature and ambient gas conditions. Dr. Okojie and Dr. Ramesham have extensive experience with packaging and reliability testing of devices.

NASA Customers: Spaceliner 100, Mars micro-missions, X2000, and New Millennium missions.
Benefits to Customers: Spaceliner 100 will enable the use of an all-optical architecture which will save weight, be immune to EMI, reduce fire hazard due to electrical shorts (it will use optical fiber rather than electrical cables for sensors and data transmission) and reduce the power consumption of each mission. Other potential uses for the device include calibration sources for spectrometers and illumination sources for uncooled infrared spectrometers.

Clearly Stated Deliverables:

1. Background literature review.
2. Perform thermal modeling of the MEMS broadband source. Construct a test matrix for each reliability test and address the packaging issues as necessary.
3. Conduct tests in static and temperature cycling conditions under changing ambient environment.
4. Perform microstructural and microchemical (where applicable) analysis to determine failure mechanisms.
5. Write report of findings.

Top Level Schedule:

FY01/Q1	Background literature search and parts acquisition.
FY01/Q2	Run static thermal tests on device. Begin performing thermal modeling.
FY01/Q3	Construct test matrix for thermal cycling study
FY01/Q4	Run thermal cycling tests for pre/post-performance, incorporate data from thermal modeling, and study/write report on results.
FY02/Q1 & FY02/Q2	Perform appropriate microanalysis tests to determine failure mechanisms in failed devices.
FY02/Q3	Construct model for failure modes
FY02/Q4	Write report on packaged device reliability.

Leveraging: Proposed packaging and reliability testing project will leverage the existing device development partnership between NASA Glenn, JPL, and Lighting Innovations Institute. In order to utilize the successful development of the MEMS light source, we must perform reliability testing of the packaged sources. NASA Glenn and JPL have experts in the field of MEMS reliability testing. Dr. Okojie performed research on the accelerometers used in air-bag deployment at Ford Motor Company and Dr. Ramesham has performed research on MEMS packaging at JPL.

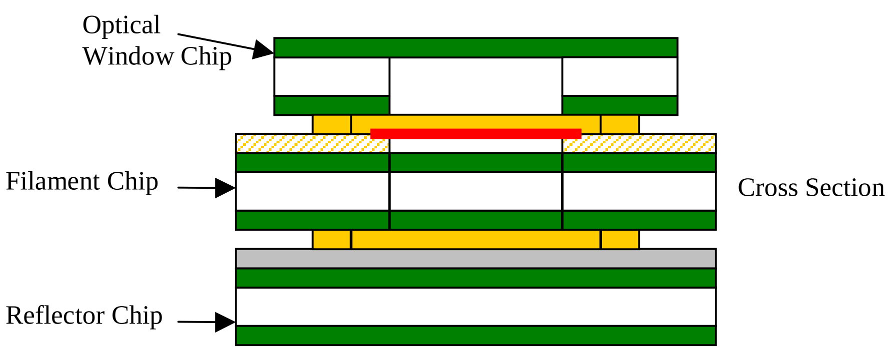

Figure 1. Packaging concept for broad band light source (chip-to-chip and filament thermal bonds exaggerated)

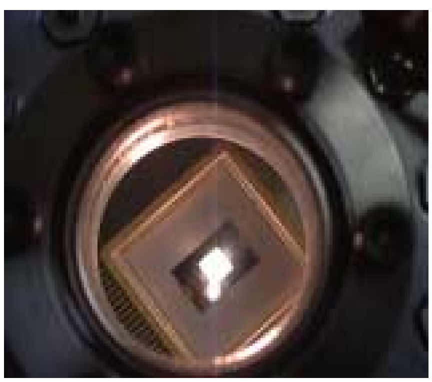

Figure 2. Microfabricated broad band light source operating at 2650 in a vacuum chamber.